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AN AUTOMATED OPTICAL DISPLAY SYSTEM FOR VISUAL PHYSIOLOGY EXPER--ETC(U)
JUL 82 J D DANIELS, T R MYERS N00014-81-K-0136
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AN AUTOMATED OPTICAL DISPLAY SYSTEM FOR VISUAL PHYSIOLOGY EXPERIMENTS*

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Abstract

Control of a visual physiology overhead projection system has been achieved by an 8085 microprocessor system, with a supporting array of a-d converters, voltage-to-current amplifiers, d-a converters, and analog switches. Image position, speed of movement, direction, length of sweep and number of sweeps can all be programmed by the operator. Handshake lines send the "start" and "end" signals to another device which correlates nerve cell activity with stimulus movement.

INTRODUCTION

For the recording of single neurons in the visual system two extreme approaches to stimulation are possible. In the manual approach the experimenter waves various pictures, props, light sources or patterns in the animal's field of view, correlating in his mind the audio output of a nerve cell response amplifier with aspects of the stimuli. In the automatic approach a programmed controller advances the electrode, attempts to separate signal from noise in the electrode amplifier and determines all nerve cell-recognized features of the stimuli: position, size, shape and movement. The controller can occlude one eye or the other for occular dominance testing. The computer associated with the controller can print out histograms of response versus stimulation and even make decisions about nerve cell classification.

The manual approach suffers from the usual problems of qualitative analysis--requirements for subjective judgement and lack of repeatibility. In our case the experimenter becomes additionally preoccupied with the physical activity necessary to move stimuli in front of the animal and he or she may miss important events (such as change in heart rate of EEG) that could affect results. The automatic approach also has drawbacks. The programmer must be completely familiar with every detail of the experiment and predict all contingencies with his code. Computer analysis becomes troublesome when patterns must be recognized or judgements with imperfect knowledge must be made. Cost rises when more and more sensors and motors are placed in system to interface with the central processor.

The <u>interactive</u> approach places the most worthwhile features of a computer controlled system at the disposal of a human experimenter who makes critical judgements and dexterous manipulations. The computer provides precise, repetitive stimuli and records the nerve spike history associated with the stimuli. The experimenter "points" the machine to the approximate field of view, moves the electrode from one nerve cell to another and adjusts surgical and optical components to ensure that the animal and stimuli are in proper condition. In short, the human provides supervison and judgement while the machine provides precise record keeping, and stimulus control.

We have designed and built an interactive computer controller for visual physiology experiments. Our machine controls X and Y servo motors for horizontal and vertical movement of a target, and a high speed shutter. It can receive input either from a joy stick and foot switch in the manual mode or from a portable parameter box in the automatic mode. The parameter box can specify speed, direction, length, delay and number of repetitions for each stimuli. Output terminals provide hand shake signals to a nerve spike counting device.

SYSTEM DESCRIPTION

Figure 1 shows an overview of the experimental set-up. The elements of our controller and its inputs and outputs are shown in crosshatch. On the left, one meter from the screen, is an animal prepared for single unit recording of visual cortex neurons. The experimenter can sit in a

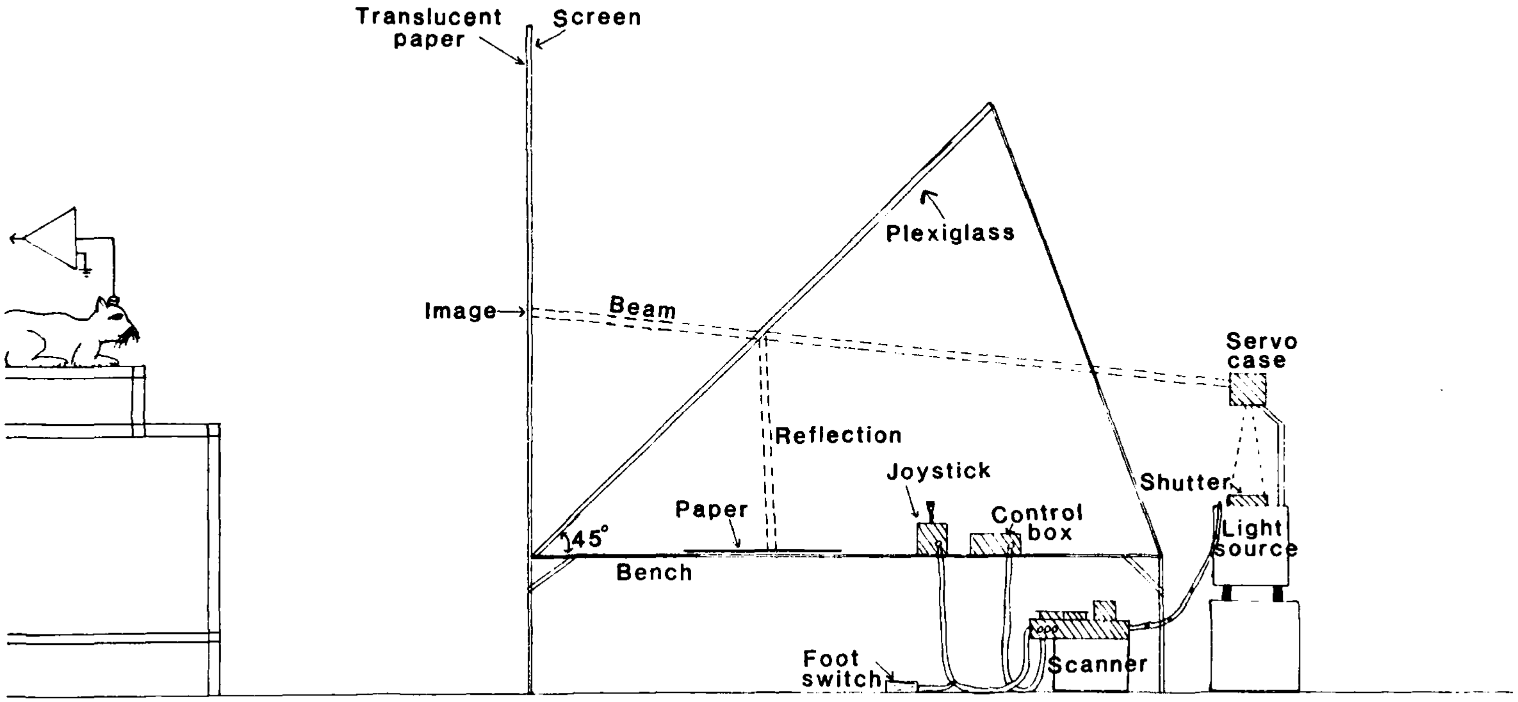

Translucent paper
Screen
Image
Beam
Plexiglass
Reflection
Paper
45°
Bench
Joystick
Control box
Shutter
Servo case
Light source
Foot switch
Scanner

Fig. 1

chair near the bench and use the manual mode to make an initial determination of a neuron's visual response preferences (see other technical notes associated with this project for details of neuron responses). The large plexiglass sheet functions as a beam splitter providing an image on a screen for the animal and a reflection down to the bench for the experimenter to draw and study. The three photographs of figures 2 provide views of (a) the main electronics board and power supply, (b) the joystick, with offset control potentiometers, and (c) the portable parameter box with its LED display and keyboard, with display functions.

SPEED Numbers entered between 000 (min) and 255 (max) are converted to degree per second speeds shown in the Speed Conversion Table. The 0-9 buttons are used.

DELAY Inter-scan delays between 00.0 sec. and 25.5 sec. may be entered. 0-9 buttons are used.

AUTO Establishes unlimited number of scans. When Scan is pressed, the machine scans ad infinitum. The scan count displayed increments after each scan. Counter goes to 000 after 255.

TRIALS COUNT Numbers entered between 000 and 255 cause scanning to halt when the scan count equals the number entered. The 0-9 keys enter the number of trials. When the scan key is pressed, the scan counter is reset to 000 and counts up to the number of trials; the machine is then halted.

<u>HALT RESET</u> <u>Halt</u> is the only key acknowledged during scanning. The display shows the number of scans completed. <u>Reset</u> is performed if pressed while the machine is halted. It resets the scan counter to 000.

<u>SCAN</u> When pressed, scanning is initiated. The display shows the scan counter, and is incremented after each complete scan.

<u>ORIGIN MANUAL</u> Opens the shutter and gives servo control over to the manual joystick. <u>The display shows the A to D conversion of the screen position of the light beam (H or V)</u>. "Enter" and "display" apply to the origin registers.

<u>CENTER MANUAL</u> Same as "origin manual" but the "center" registers are used instead of the "origin" registers.

<u>ENTER</u> The A to D conversion of the joystick screen position is entered into the "origin" or "center" registers, depending upon the function selected. The H or V positions are shown in the display and the light beam is frozen at the entered point. Either manual button returns joystick control.

<u>DISPLAY</u> The light beam is frozen at the existing point in the selected register. The H or V positions are shown in the display.

<u>H or V</u> Puts the H or V coordinate of the origin, center, or joystick into the display.

<u>0-9</u> Enters numbers into the speed, delay, or trials registers. The display shows the updated registers.

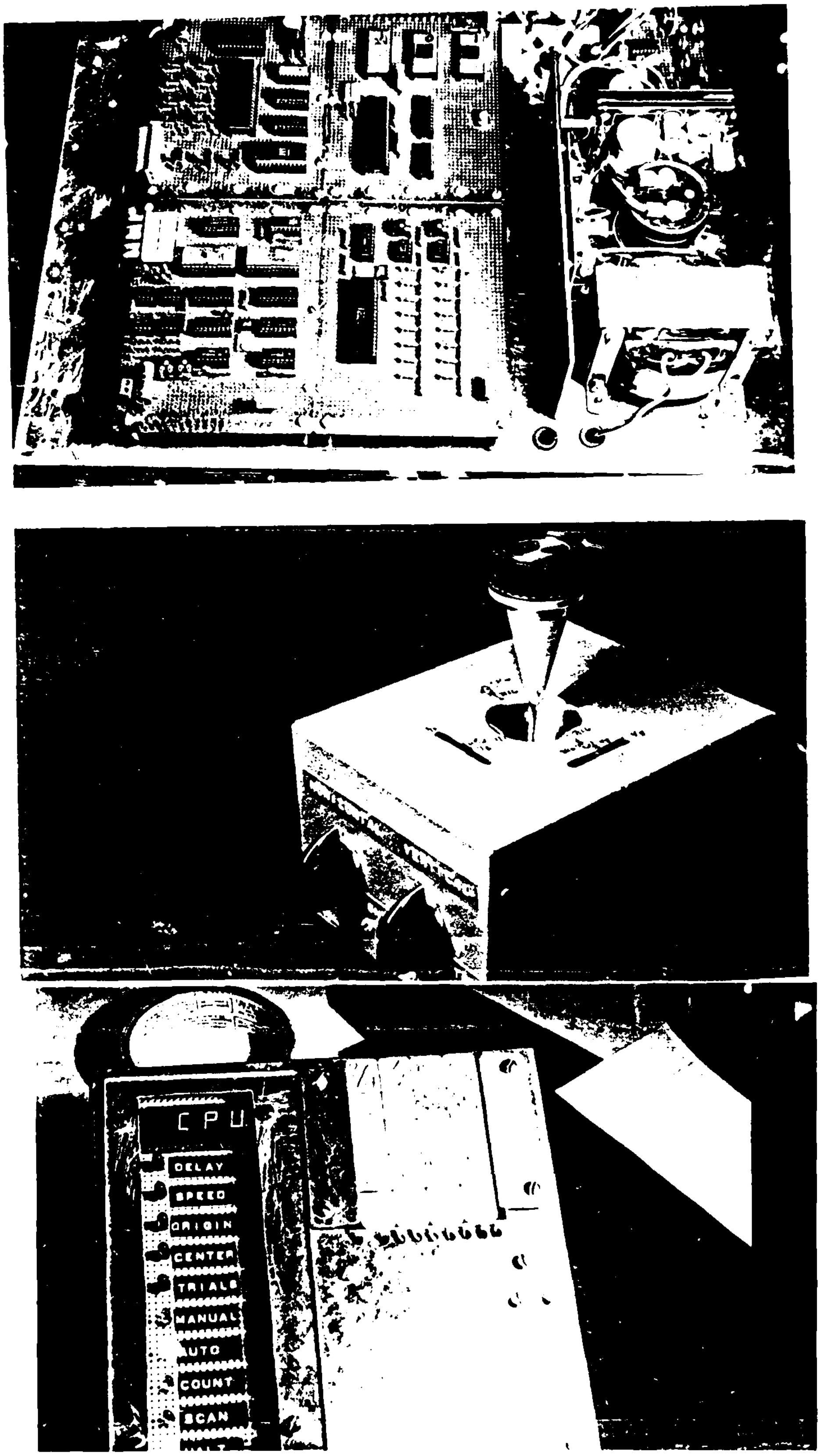


Fig. 2

ALGORITHM FOR DIRECTED MOVEMENT

Because of memory and coding limitations we required a method of moving the stimulus (along a particular orientation) which could be done by simple calculation, without resort to large table look-up extrapolations schemes. Basically, we need to avoid computing or storing trig functions. As can be noted from the keyboard function table the operator does not enter the angle of a scan, rather the origin and center are put in the system through A to D conversion, with the help of the operator using the joystick.

Figure 3 and following discussion explain the algorithm.

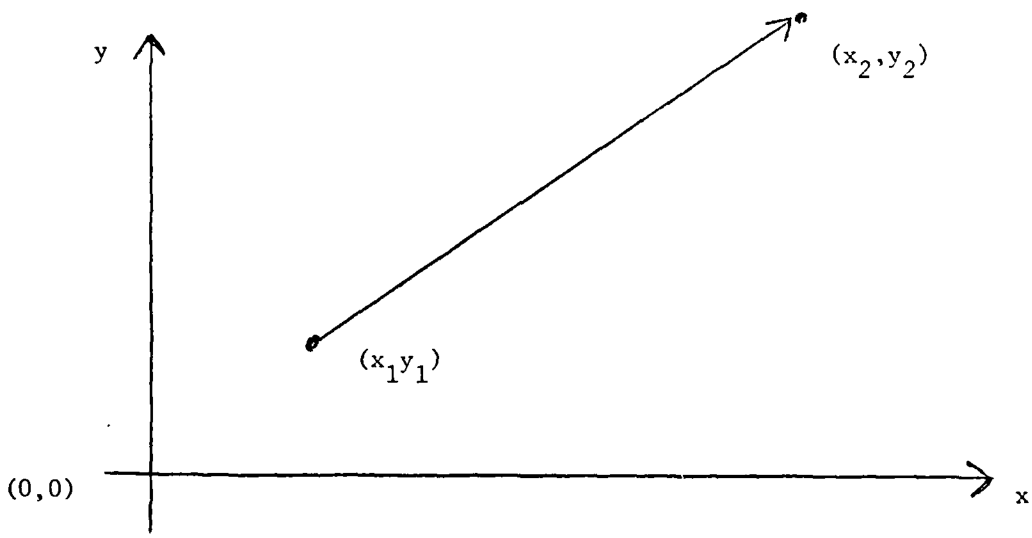


Fig. 3

Using "center" and "origin" information the program computes "end".

assume origin $= x_1, y_1$

end $= x_2, y_2$.

The program converts any pair of origin and end points to a special problem of movement <u>away</u> from (0,0) point into the upper right hand quadrant. See Figure 3 for an example. This conversion establishes that

$$x_2 > x_1$$
$$y_2 > y_1$$
$$dx > dy.$$

where

$$dx = x_2 - x_1$$
$$dy = y_2 - y_1.$$

Four more parameters are defined:

$$I_1 = 2dy$$
$$I_2 = 2(dy-dx)$$
$$d = 2dy-dx$$

c = dx(digitizes dx to be an integer counter value).

To begin,

$$x = x_1$$
$$y = y_1.$$

For the algorithm, (x,y) = OUTPUT.

If c=0, then STOP.

There are two loops in the algorithm program--

LOOP TOP:	$x = x + 1$
	If $d < 0$, THEN GO TO $\underline{d < 0}$.
	If $d > 0$, THEN GO TO $\underline{d > 0}$.
$\underline{d < 0:}$	$d = d + I,$
	GO TO LOOP BOTTOM
$\underline{d > 0:}$	$d = d + I_2$
	$y = y + 1$
	GO TO LOOP BOTTOM
LOOP BOTTOM:	$(x, y) \rightarrow$ OUTPUT
	$c = c - 1$
	IF $c = 0$, THEN STOP GO TO LOOP TOP

The program can also be stopped by a hardware interrupt.

In the limit, as $x \rightarrow \infty$, we achieve the line equation

$$y = mx + b$$

where

$$d = (\frac{1}{m} dy - dx) \cdot K$$

[K = constant of proportionality]

$$dy = m\, dx$$

so

$$\lim_{x \rightarrow \infty} d = 0.$$

Output is digitized to eight bit resolution. The short horizontal and diagonal line segments generated on the screen by the algorithm are used to achieve the illusion of a single direction, oriented, movement. Speed is determined in a separate timing loop.

Figure 4 is a photograph of the screen while a 40 cm. movement of a tiny spot is executed. The arc of the sweep length is 20 degrees and each of the 60 or so dots represents about a third of a degree movement either horizontally or at 45 degree angle. With the 8-bit D-to-A conversion of the system a slightly choppy movement at low speeds can be detected by a human observer one meter distant from the screen. At speeds greater than 10 degrees per second movement looks reasonably smooth to a human observer. On nearly all kitten and cat nerve cells tested at low speed we find no bursting rate in synchrony with the slightly choppy movement. We conclude that 8-bit accuracy is just sufficient to stimulate kitten nerve cells with apparently smooth movement.

The speed converstion chart shows a range from 0.2 degrees per second up to 140 degrees per second with most emphasis on speeds less than 10 degrees per second. Sweep length maximum is nominally 22 degrees, determined somewhat by the limitations of the MFE scanning servo motors, and otherwise by the scanner-to-screen distance.

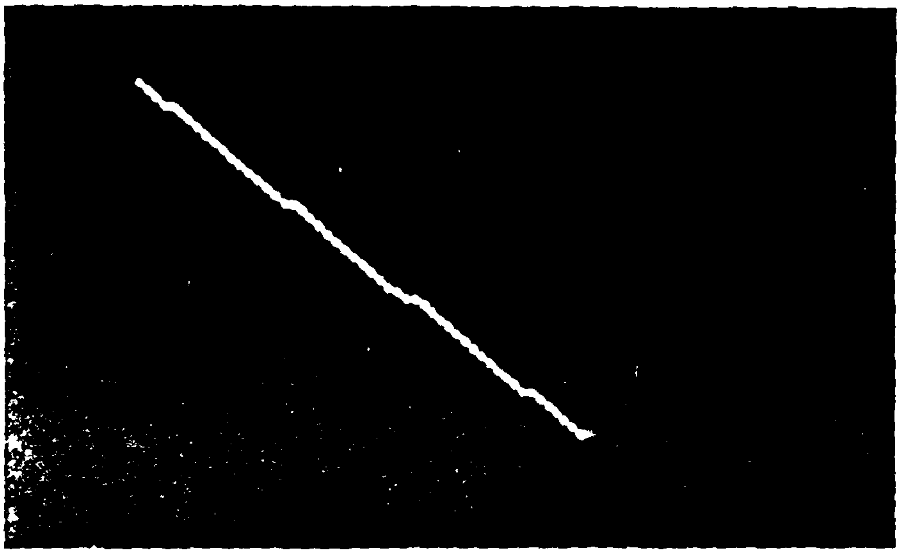


Fig. 4

HARDWARD SCHEMATIC

We show the major hardware components in Figure 5. It provides a block diagram overview of the circuitry, including input and output. The system features Intel's 8085 microprocessor, 8279 40 pin keyboard and display chip and 8155 RAM I/O with 3 ports, each of which are utilized by the system. In addition, TI's 2508 200 nanosecond 1K X 8 EPROM and National Semiconductor's MM5357 CMOS monolithic A to D converter provide more large scale integration of electronic function.

The 8085 is Intel's 70-fixed-instructions 8 bit microprocessor, which executes statements stored in the 2508 ROM's. We operate it at 4 MHZ. Five control lines and two interrupt allow interface to the slave chips in the circuit. The 8279 is a specialized 40 pin LSI chip which handles all keyboard and display tasks, with signals from the 8085. The 8155 stores dynamic values, provides output ports for digitized signals on the way to D→A converters, and also for control of the LF13331 analog switch set the one amp op amps--LH0021--drive 8 ohm MFE scanning motors which control the x and y positions of the projection mirrors. A bank of 8212 latches handle input and output for the manual control mode, including the status display lights on the programmer's selection module. Joystick potentiometer signals pass through MM5357 8 bit A→D converters. Their end-of-conversion pulses are taken in by the 8085, which in turn delivers start-of-conversion control.

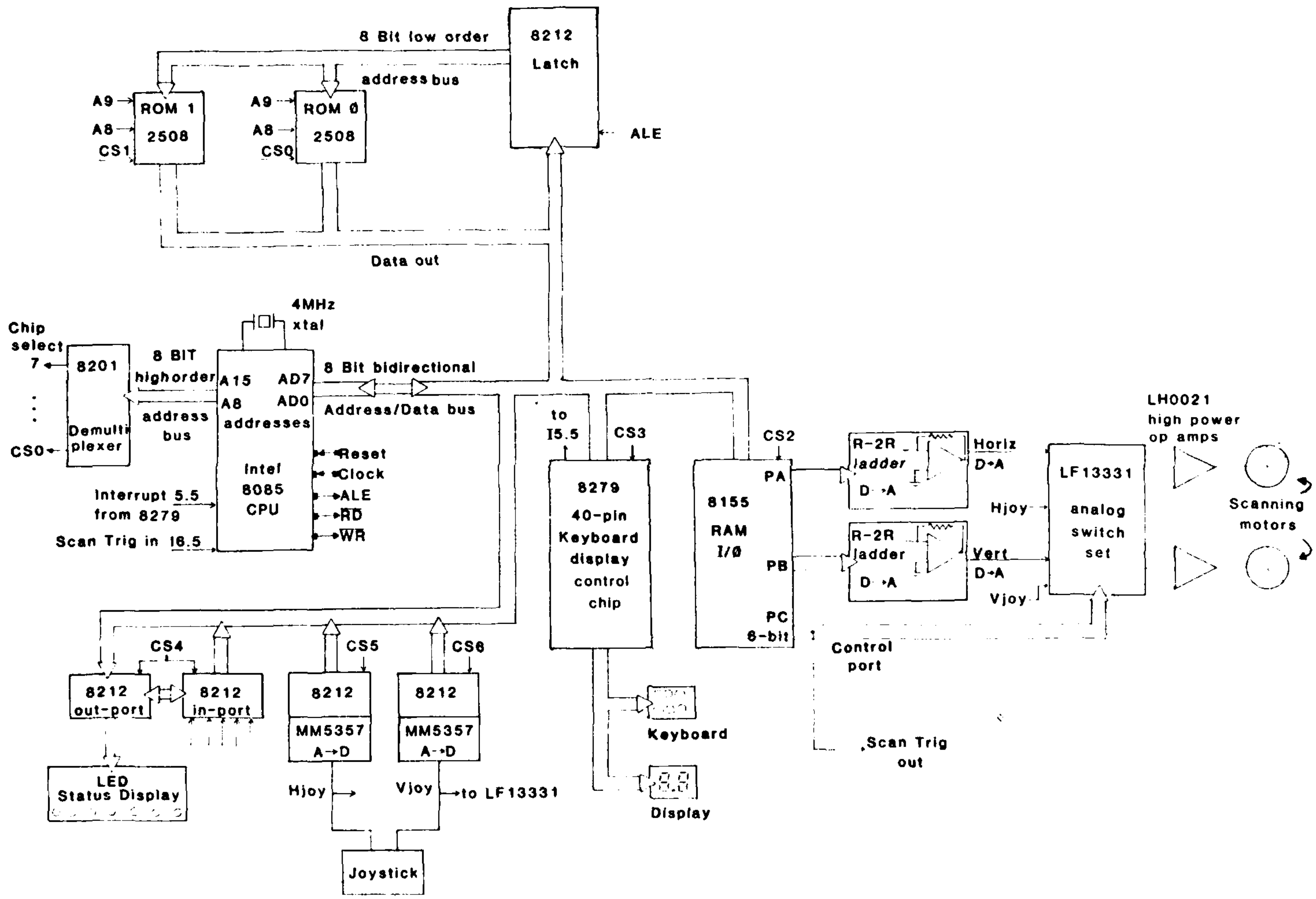

8212
Latch
8 Bit low order
address bus
ALE
A9
A8
CS1
ROM 1
2508
A9
A8
CS0
ROM Ø
2508
Data out
4MHz
xtal
Chip
select
7
8201
Demultiplexer
CS0
8 BIT
highorder
address
bus
A15
A8
addresses
AD7
AD0
Intel
8085
CPU
8 Bit bidirectional
Address/Data bus
Reset
Clock
ALE
RD
WR
Interrupt 5.5
from 8279
Scan Trig in 16.5
to
I5.5
CS3
8279
40-pin
Keyboard
display
control
chip
CS2
8155
RAM
I/Ø
PA
PB
PC
6-bit
R-2R
ladder
D→A
Horiz
D→A
R-2R
ladder
D→A
Vert
D→A
Hjoy
Vjoy
LF13331
analog
switch
set
LH0021
high power
op amps
Scanning
motors
Control
port
Scan Trig
out
Keyboard
Display
CS4
8212
out-port
8212
in-port
LED
Status Display
CS5
8212
MM5357
A→D
CS6
8212
MM5357
A→D
Hjoy
Vjoy
to LF13331
Joystick

Fig. 5

SOFTWARE FLOWCHARTS AND THE MEMORY MAP

The entire assembly language code which fits in 2K of ROM and was written without the benefit of an assembler. A complete listing is available from the authors. Basically, when the system is on and running it is either reading the keyboard or executing a scan (moving a target).

Details of the keyboard monitor software are given in the figure 6 flowchart. Note that a "wait loop" exists for the condition in which no buttons are pressed. Once the scan button is pressed an interrupt is executed and the particulars of the scan program are shown in figure 7. Here the calculations are made for the decision parameter "d", a shutter is opened and closed at appropriate times, digital to analog outputs are updated, and a delay for speed control is generated.

The memory map for the system is shown in figure 8. From bottom to top we have ROM, RAM, input-output and open expansion. The ports of the RAM I/O chip are addresses in memory; port A is assigned to horizontal movement, port B to vertical movement and port C is a control port. Figure 9 at the bottom shows the four parameters assigned to port C, including shutter control. The top half of figure 9 shows how the status lights are controlled from a port which uses two 8212's. The right side of figure 8 relates the memory map to chip select lines shown in figure 5. In all, $1C00_{16} \cong 7000_{10}$ memory locations are used for this system.

SUMMARY

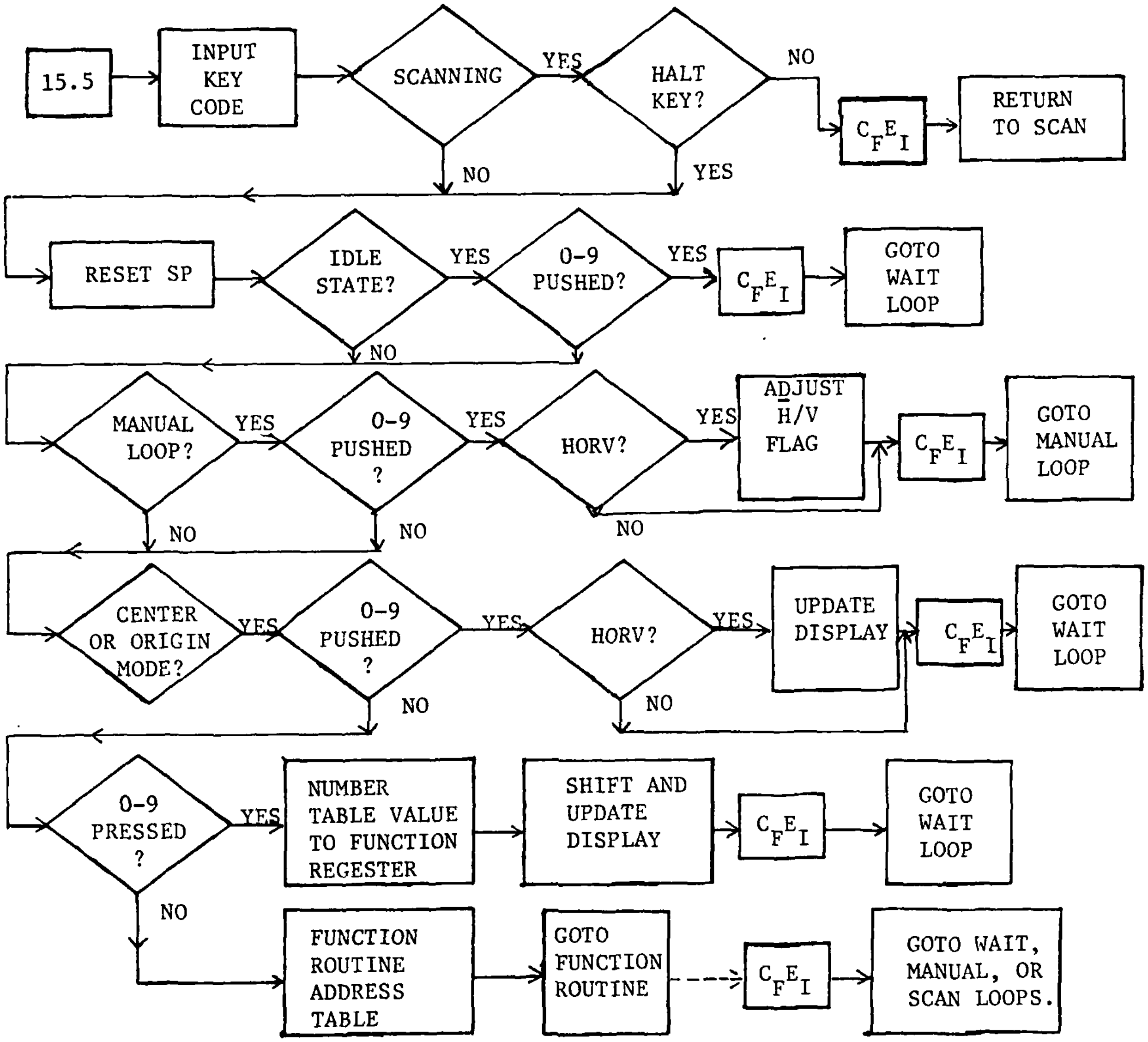
An interactive automated low cost microprocessor driven optical display system has been described. Total cost of the hardware including logic chips, power supplies, cables, servo motors, optical and mechanical hardware is about $700. Development time was 9 months of twelve hours per week work of a senior engineering student. The hardware in its present form is not general purpose or portable; it is custom built for our particular lab needs. However, it fills those needs completely and makes the tedious work of collecting data on single neuron responses to visual stimuli much more productive than either the primitive manual method or the unnecessarily costly fully-atuomated method. The ideas of the design can be extended easily to other interactive optical displays systems.

ACKNOWLEDGMENT:

We thank Marjory Schwartz for help with graphics.

KEYBOARD MONITOR

$C_F E_I$ ≡ CLEAR Keyboard FIFO Regester, Enable Interrupts.



SCAN START INTERRUPT LOCATED AT $02C0_{16}$

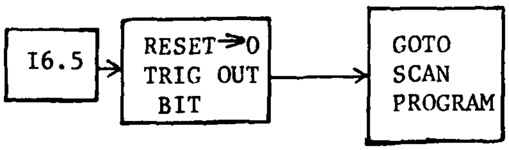


Fig. 6

SCAN PROGRAM LOCATED AT $04A0_{16}$.

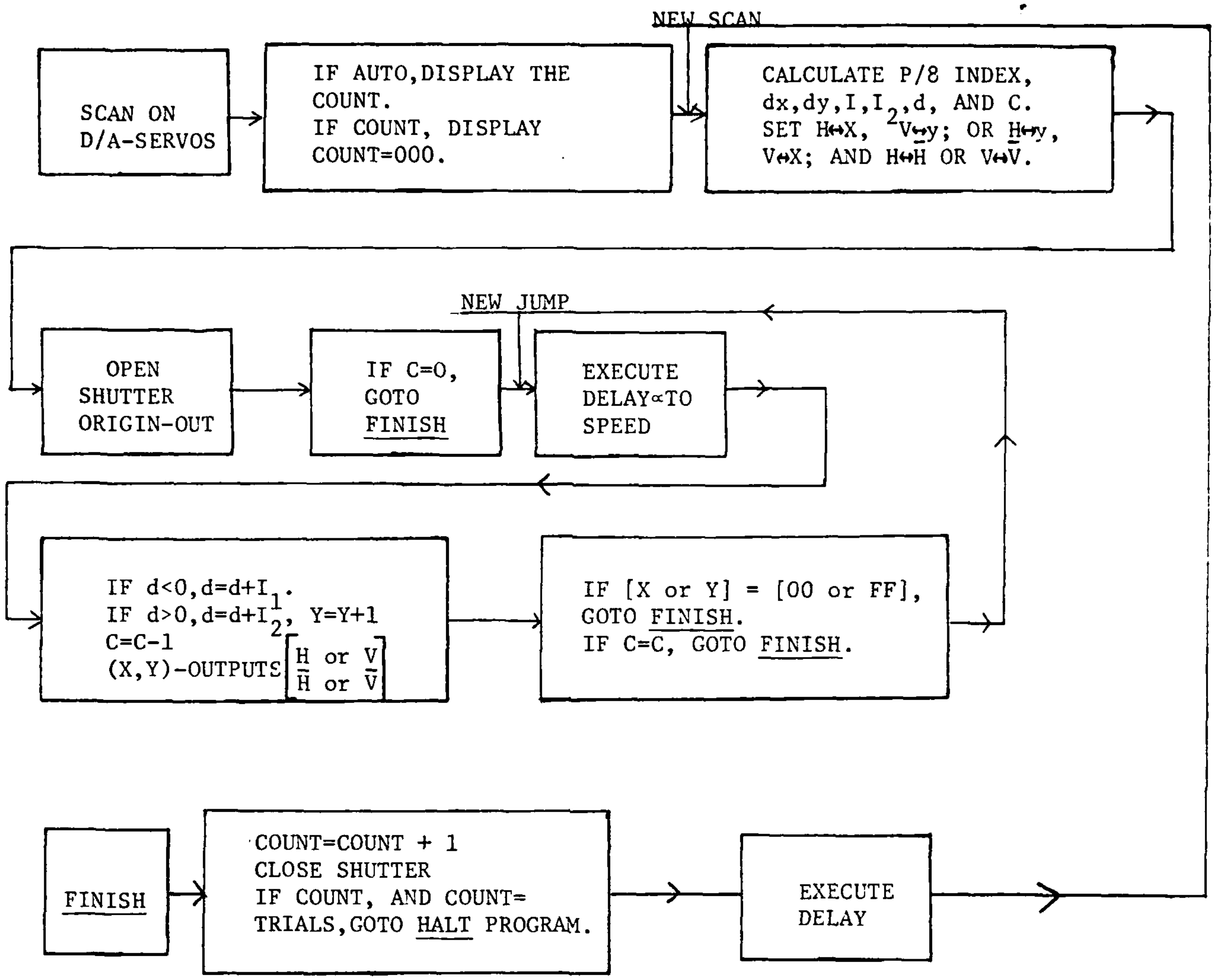


Fig. 7

MEMORY/PORT MAP

MEMORY MAPPED I/O SYSTEM

ADDRESS	CONTENTS	CHIP SELECT
0000 03FF	ROM Ø (2K) 2508	$\overline{CS0}$
0400 07FF	ROM 1 (2K) 2508	$\overline{CS1}$
0800 08FF	RAM (256) 8155	$\overline{CS2}$
0900	COMMAND/STATUS REGESTER:8155	
0901	PA: H_D/A	
0902	PB: V_D/A	
0903	PC: CONTROL PORT	
0C00	KEYBOARD/DISPLAY DATA I/O: 8279	$\overline{CS3}$
0C01	KEYBOARD/DISPLAY CSR: 8279	
1000	STATUS RD/WR PORT: 2x8212	$\overline{CS4}$
1400	$\overline{\text{HAID}}$ PORT IN 8212	$\overline{CS5}$
1800	$\overline{\text{VAD}}$ PORT IN 8212	$\overline{CS6}$
1C00 1FFF	OPEN	$\overline{CS7}$

Fig. 8

STATUS PORT 1000_{16}

$\overline{A}$/C	$\overline{H}$/V	$\overline{S}$/H	M_1	M_0	F_2	F_1	F_0

$\overline{A}$/C=0: AUTO MODE $\overline{A}$/C=1:COUNT MODE
$\overline{H}$/V=0: HORIZONTAL COORD.→DISPLAY
$\overline{H}$/V=1: VERTICAL COORD.→DISPLAY
$\overline{S}$/H=0: SCANNING $\overline{S}$/H=1:HALTED

M_1 M_0	MODE
0 1	MANUAL
1 0	AUTO
1 1	COUNT

$F_2F_1F_0$	FUNCTION	
0 0 0	DELAY	
0 0 1	SPEED	
0 1 0	ORIGIN	
0 1 1	CENTER	
1 0 0	TRIALS	
1 0 1	MANUAL	IDLE
1 1 0	AUTO	MODE
1 1 1	COUNT	

CONTROL PORT $0C03_{16}$

0	0	0	0	SCAN TRIG OUT	SHUTTER	D/A OUT	JOY OUT

D/A OUT ┐ 1 SELECTS OUTPUT TO SERVOS
JOY OUT │ 0 BLOCKS OUTPUT TO SERVOS
SHUTTER:┘ 1 OPENS SHUTTER; 0 CLOSES SHUTTER
SCAN TRIG OUT: 1 OR 0 SENT TO HISTOGRAMMER TRIG IN

Fig. 9

SPEED CONVERSION TABLE

SPEED	DEG/SEC	SPEED	DEG/SEC
000(MIN)	.20	130	22
005	.20	135	23
010	.21	140	24
015	.22	145	25
020	.23	150	26
025	.24	155	27
030	.26	160	28
035	.27	165	29
040	.29	170	31
045	.30	175	32
050	.32	180	34
055	.34	185	36
060	.37	190	38
065	.40	195	40
070	.43	200	43
075	.47	205	47
080	.52	210	50
085	.58	215	53
090	.66	220	60
095	.75	225	64
100	.89	230	70
105	1.1	235	83
110	1.4	240	96
115	1.9	245	111
120	3.1	250	125
125	8.0	255(MAX)	140

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